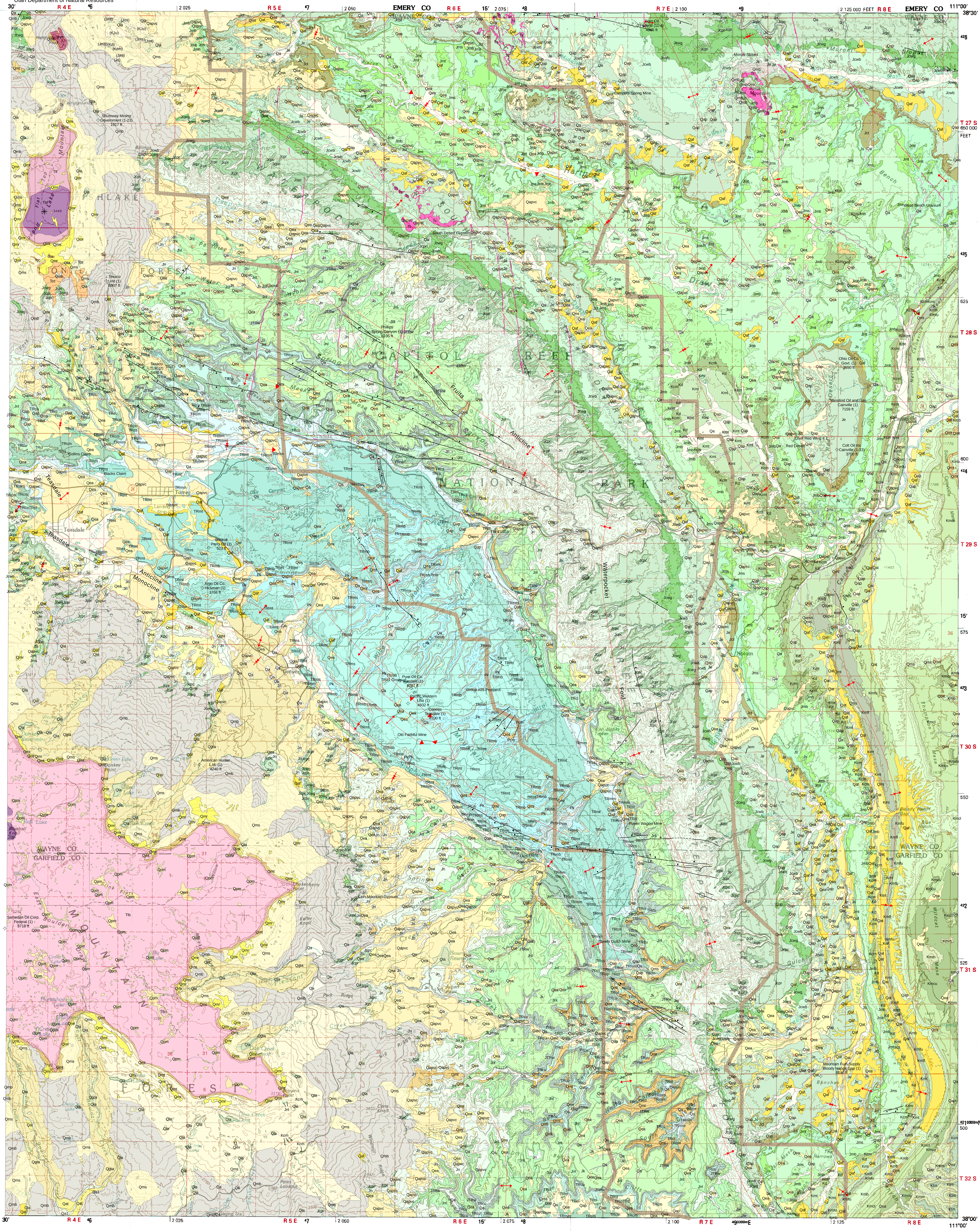
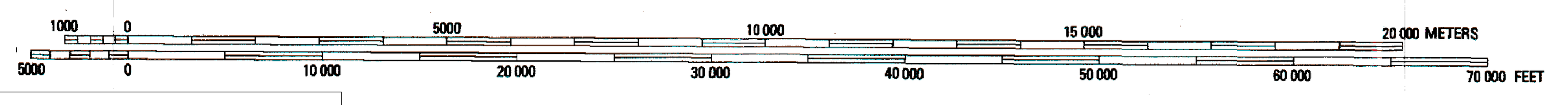
Utah Geological Survey
a division of
Utah Department of Natural Resources

Plate 1
Utah Geological Survey Open-File Report 489
Interim Geologic Map of the East Half of the Loa 30' x 60' Quadrangle





Project Manager: Donald L. Clark and Grant C. Willis
Digital Cartography: Buck Ehler, Darryl Greer, and Paul Kuehne

Map Explanation

- Contact
- Contact, approximately located
- Dike, well located
- Dike, approximately located
- Sill
- Fault, well located, bar and ball on downthrown side; where no bar and ball, downthrown side unknown
- Fault, approximately located, bar and ball on downthrown side
- Fault, concealed
- Landslide main scarp
- Anticline, well located; arrow shows direction of plunge; dotted where covered
- Anticline, approximately located; arrow shows direction of plunge
- Syncline, well located; arrow shows direction of plunge; dotted where covered
- Syncline, approximately located; arrow shows direction of plunge
- Monocline, well located; dotted where covered
- Marker bed, well located
- Marker bed, approximately located
- 12 Strike and dip of inclined bedding
- Exploration well, plugged and abandoned; figures give total depth
- Mines
- Volcanic vent

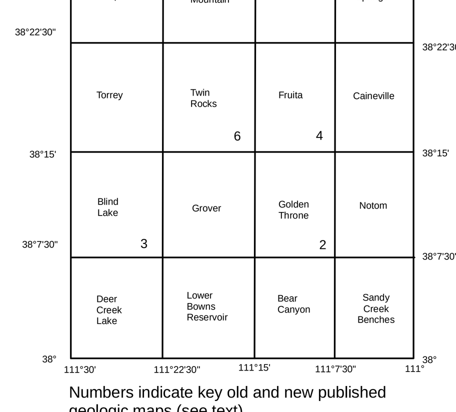
This map is a plot of Geographic Information System (GIS) files created to visually represent the content of the GIS data files. It is not a published map and it contains many features that do not meet UGS cartographic standards, such as automatically generated labels that may overlap other labels and lines.

Scale 1:62,500
Contour Interval - 50 Meters

Interim Geologic Map of the East Half of the Loa 30' X 60' Quadrangle, Wayne, Garfield, and Emery Counties, Utah

By
Hellmut H. Doelling and Paul Kuehne
2007

Index Map to 7.5' Quadrangles



Numbers indicate key old and new published geologic maps (see text)

This geologic map was funded by the Utah Geological Survey and U.S. Geological Survey, National Cooperative Geologic Mapping Program, through USGS STATEMAP award number 05HQAG0084.

Interim Geologic Map of the East Half of the Loa 30′ x 60′ Quadrangle, Wayne, Garfield, and Emery Counties, Utah

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UTAH DNR GEOLOGICAL SURVEY

OPEN-FILE REPORT 489

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2007

DESCRIPTION OF GEOLOGIC UNITS
EAST HALF OF LOA 30’ x 60’ QUADRANGLE

Alluvial Deposits

Qa **Alluvial deposits (Holocene) –** Sand, silt, clay, granules, pebbles, cobbles, and sparse boulders in areas where young alluvium and younger alluvial-terrace deposits cannot be differentiated on the map; as much as 30 feet (10 m) thick, but generally much thinner.

Qa1 **Young alluvium (Holocene) –** Sand, silt, clay, granules, pebbles, cobbles, and sparse boulders present as channel fills along the more active streams and washes; unconsolidated, poorly to well sorted; thickness varies widely, but commonly less than 30 feet (10 m) thick.

Qat **Younger alluvial-terrace deposits (Holocene) –** Sand, silt, clay, granules, pebbles, cobbles, and sparse boulders, poorly to well sorted, and unconsolidated; channel and flood plain deposits; present in terraces adjacent to modern stream channels; 10 to 40 feet (3-12 m) above stream level; thickness varies widely, but locally may exceed 40 feet (12 m).

Qato **Older alluvial-terrace deposits (upper to middle Pleistocene) –** Mostly silt to cobbles, angular to rounded; contains chert, limestone, sandstone, siltstone, conglomerate, dolomite, and volcanic boulders to 2 feet (0.6 m) in diameter, but mostly pebbles and cobbles up to 2 inches (5 cm) in diameter; poorly to well sorted; basal parts are generally more coarse; deposits are at irregular levels above modern drainages and above younger alluvial terrace deposits; Eddleman (2005) worked out several terrace level ranges , but they are not differentiated on this map because of scale constraints; 0 to 30 feet (0-10 m) thick.

Qaf **Alluvial fans and local alluvium (Holocene to upper Pleistocene) –** Sand, silt, clay, granules, cobbles, and sparse boulders; angular to subrounded clasts; cut-and-fill channel features locally present; crudely bedded to unstratified; deposited as debris flows at the foot of cliffs, ridges, and higher ground and at the mouths of some streams and washes; thickness commonly less than 50 feet (15 m).

Qap **Pediment-mantle deposits (Mostly upper Pleistocene, locally may include Holocene or middle to lower Pleistocene) –** Boulders, cobbles, and pebbles in matrix of granules, sand, silt, and clay; rounded to subangular, generally poorly sorted and fining upward; covers bedrock surfaces between drainages at various levels above local base level; commonly less than 50 feet (15 m) thick.

Mixed-Environment Deposits

Qapvc Mixed pediment-mantle and colluvial deposits with volcanic boulders (Mostly upper Pleistocene, locally may include Holocene or middle to lower Pleistocene) – Same as Qap, except contains significant quantities of volcanic (mostly basaltic andesite) boulders and includes colluvium that commonly heavily drapes the sides of canyons below the pediment surface; generally gray to dark gray in color; undersides of many volcanic boulders coated with white calcium carbonate (caliche in calcic soil); locally grades into Qap deposits; commonly less than 50 feet (15 m) thick.

Qea Mixed eolian and alluvial deposits (Holocene to middle Pleistocene) – Sand and silt of eolian origin interspersed with silt, sand, and minor gravel of alluvial (sheet-wash) origin; poorly stratified; upper parts generally dominated by eolian deposits; commonly displays a calcic soil (caliche) horizon near the top; generally covers pediment-mantle deposits or low flat areas; less than 50 feet (15 m) thick.

Eolian Deposits

Qes Eolian sand and silt deposits (Holocene to Upper Pleistocene) – Unconsolidated sand and silt deposits in wind-deposited sheets or low dunes; light-orange-brown, nearly white, or light-brown, fine- to medium-grained, well-sorted; especially common in areas underlain with the Entrada Sandstone or similar sandstone deposits; 0 to 20 feet (0-6 m) thick.

Mass Wastage Deposits

Qmt Talus and rock-fall deposits (Holocene to upper Pleistocene) – Rock-fall blocks, boulders, angular gravel, sand, and silt; locally includes colluvium; deposited on slopes below cliffs and steep slopes; nature of clasts dependent on up-hill source; only larger deposits mapped; thickness generally 15 feet (4.5 m) or less.

Qms Slumps and landslide deposits (Holocene to lower Pleistocene) – Coherent to broken and jumbled masses of bedrock to soft clayey hummocky materials that have moved downslope; locally includes colluvium; very poorly sorted; largest deposits surround volcanic rocks of Boulder Mountain and Flat Top and consist of jumbled masses of volcanic rock; near Flat Top many Cretaceous and Jurassic units have moved downhill by gravity, but are still partly recognizable in outcrop, such as KJu (Cretaceous and Jurassic units undifferentiated), Km (Mancos Shale), Kd (Dakota Sandstone), Kcm (Cedar Mountain Formation), Jmb (Brushy Basin Member of Morrison Formation), Jms (Salt Wash Member of Morrison Formation), Jmt (Tidwell Member of Morrison Formation), Js (Summerville Formation), and Jct (Curtis Formation); varied thicknesses.

Qmr Rock glacier deposits (Holocene to middle Pleistocene) – Boulders, angular and blocky, with minor matrix, forming lobate heaps that locally creep downhill; derived from volcanic rocks of Boulder Mountain and Flat Top (Thousand Lake Mountain); varied thicknesses.

Qmb **Igneous boulder deposits (Holocene to Pleistocene) –** Igneous boulders in old landslides, old till, and colluvial deposits that heavily mantle the sides of Boulder Mountain and Flat Top (mostly basaltic andesite) and Black Mountain (blocks from dikes and sills); predominantly poorly sorted mixtures of silt, sand, small rock fragments and pebbles make up the matrix; generally gray to dark-gray in color; compositions vary reflecting buried bedrock deposits, but lesser components commonly include polished chert pebbles, quartzite, and sandstone pebbles, and in other areas light-hued volcanic tuff and clay; may locally be more than 50 feet (15 m) thick.

Glacial and Other Deposits

Qgta **Glacial till and alluvial outwash (Upper to middle Pleistocene) –** Morainal deposits of very poorly sorted clay, sand, pebbles and large to small volcanic boulders; common boulders are conglomerate, sandstone, siltstone, shale, and limestone, all generally unstriated; lateral, recessional, and terminal moraines, knobs, and kettles are present in deposits; locally the till overlies outwash gravel, which extends downslope from morainal deposits; 18.0±1.4 to 22.1±1.8 ka (Marchetti, 2002); as much as 200+ feet (60 m) thick.

Qpm **Peaty marsh deposits (Holocene to upper Pleistocene) –** Mostly earthy sand-, silt-, and clay-sized, weathered, extrusive igneous rock (regolith) mixed with decaying vegetation collected in depressions gouged out by Pleistocene glacial ice and commonly containing small lakes and ponds filled by rain and snowmelt; inasmuch as lake water prevents the vegetal matter from oxidizing, such deposits commonly emit foul odors; commonly 0 to 2 feet (0-60 cm) thick, locally more; deposits are generally so thin that weathered volcanic rock commonly juts out amongst the deposits.

Qla **Lacustrine and alluvial deposits (Holocene to upper Pleistocence) –** Mostly sand-, silt-, and mud-sized volcanic particles carried into depressions that are commonly filled by bogs, lakes, and reservoirs; occurs on till, volcanic boulder, and landslide deposits on the flanks of Thousand Lake Mountain and Boulder Mountain; lakes and reservoirs are filled by run-off in spring and gradually shrink until winter; crudely to well stratified; 0 to 20 feet (0-6 m) thick.

--unconformity--

Ts **Dikes and sills (Pliocene) –** Composition varies with increasing alkali content
Td from basalt to trachybasalt to tephrite and phenotephrite; referred to as shonkinite by Gartner (1986) and Delaney and Gartner (1995), and as syenite and diabase by Williams and Hackman (1971); gray- to dark-green-gray, consisting chiefly of augite, biotite, hornblende, feldspar, labradorite, anorthoclase, olivine, thomsonite, and analcite (Gartner, 1986); dikes are as much as 3 miles (4.8 km) in length, nearly vertical and appear to cut sills (Ts) and intrude into Triassic to Upper Jurassic sedimentary rocks;

some sills intrude into several sedimentary horizons, mostly into Middle and Upper Jurassic rocks; resistant sills are a few inches up to nearly 100 feet (30 m) in thickness; dikes are 0 to 10 feet (0-3 m) wide; K-Ar ages from 3.4±0.2 to 4.7±0.3 Ma (Delaney and Gartner, 1995), $^{40}Ar/^{39}Ar$ age 4.35±0.04 Ma (unpublished UGS data).

Tbb Tbf **Basalt flows of Boulder Mountain and Flat Top (Miocene?) –** Basalt and potassic trachybasalt (figures 1 and table 1); gray to black; phenocrysts of olivine, pigeonite, and bytownite in a groundmass of fine-grained plagioclase (Williams and Hackman, 1971), pyroxene, olivine, and magnetite; dense and resistant; present as heavily eroded cinder cones and basalt that partially cover latite flows of Boulder Mountain (Tlb) and Flat Top (Tlf); similar flows have K/Ar ages of 16 to 6 Ma on Awapa Plateau (Mattox, 1991), $^{40}Ar/^{39}Ar$ age pending from this study; up to 300 feet (90 m) thick.

Tlb Tlf **Latite lava flows of Boulder Mountain and Flat Top (Miocene? to Oligocene?)** Latite lava flows (figures 1 and table 1) that cap Boulder Mountain (Tlb) and Flat Top (Tlf); mostly medium to dark gray-brown overall; phenocrysts comprise 35 to 65 percent of porphyritic rock and consist of plagioclase feldspar, pyroxene, and magnetite; phenocrysts mostly range from 0.1 to 0.4 inches (3 - 10 mm) across; groundmass is mostly plagioclase with subordinate pyroxene, magnetite, and hematite (Smith and others, 1963); described as porphyritic andesite by Smith and others (1963), as basaltic andesite by Williams and Hackman (1971), and as trachyandesite by Mattox (1991); lava plots as latite (high potassium trachyandesite) on TAS (total alkali-silica) diagram from Le Bas and others (1986) (figure 1); hard and resistant, edges of map units form spectacular cliffs; at several places on Boulder Top two or three flow units are recognizable along cliffs (Smith and others, 1963); K/Ar ages are 24.5 Ma (Best and others, 1980) and 25.2±1.6 to 23.2±1.5 Ma (Mattox, 1991) from localities west of the map area, $^{40}Ar/^{39}Ar$ age pending from this study; upper surface commonly heavily modified by glaciation; as much as 700 feet (120 m) thick.

Tvh **Lava flows and lahars of Hens Hole Peak (Oligocene?) –** Trachyte lava flows and lahar deposits with some welded tuff and ash-flow tuff (figures 1 and table 1), pale-red to red-gray to gray; lahar deposits with clast diameter up to 1.5 feet (0.5 m) in matrix of light gray to brown sand and ash; unit may correlate with trachyte flows of Deer Springs Draw exposed in Geyser Peak quadrangle to the north with a K/Ar age of 26.3 Ma (Nelson, 1989); 350 feet (100 m) thick.

--unconformity--

Tc **Clastic rocks of Flat Top (Eocene?; includes upper Eocene, Duchesnean) –** Sandstone, conglomerate, siltstone, marly siltstone and mudstone; very light brown, green-gray, light-gray, and pink-gray; sandstone has mixed lithology that creates “salt-and-pepper” appearance, is mostly poorly sorted, fine to coarse grained, and commonly gritty or pebbly, friable and poorly cemented to uncemented, exhibits limonitic streaks and is commonly cross-bedded; conglomerates are poorly cemented in matrix of coarse sand with subrounded to subangular cobbles to 4 inches (10 cm) in diameter, some flattened and discoidal, composed mostly of quartzite with a small percentage of silicified limestone and volcanics; siltstone is limonitic and argillaceous, breaks up into small equidimensional fragments, and breaks conchoidally; marly siltstone breaks into very small chips; all forms steep slope with thin, better-cemented, but friable ledges; yielded bone fragments of *Telatoceras*, an extinct Duchesnean-age rhinoceros (DeBlieux, 2006); more than 400 feet (120+ m) exposed, but incomplete; no lower or upper contacts exposed.

--unconformity? (not in contact)--

Tcc Carbonate and clastic rocks of Flat Top (Eocene? to Paleocene?) – Interbedded calcarenite, crystalline limestone, conglomeratic calcarenite, intraformational conglomerate, marl and sandstone; also some chalky highly calcareous beds and some limy dolomite; calcarenite is very light to light gray and pink gray, contains scattered quartz grains, is mostly fine to medium grained, medium sorted, hard, resistant, and weathers into thick ledges with limestone, locally pebbly or containing very small white blebs and stringers of white chert; limestone is very light to light gray and gray pink, micritic to very finely crystalline; conglomeratic calcarenite is light brown gray, with mostly matrix-supported, subrounded to subangular quartzitic pebbles as much as 1 inch (3 cm) across; intraformational conglomerate is very light to light gray, with 2- to 3-inch (5-8 cm) clasts of crystalline limestone in fine-grained calcarenite matrix; marl is light gray brown, soft and earthy weathering; and sandstone is light gray brown, fine to coarse grained, subangular to subrounded, composed of calcite and quartz grains, poorly consolidated or cemented, slope forming; locally crops out under thin landslide deposits composed of volcanic debris south and southwest of Flat Top; age uncertain; 250 feet (76 m) exposed in area, but thickness unknown.

--*contact not exposed in quadrangle*--

Ktm Tarantula Mesa Sandstone (Upper Cretaceous, upper Campanian) – Sandstone is yellow gray and light yellow brown, mostly fine grained, porous, contains local conglomeratic intervals with clasts to 1-inch (2.5 cm) in diameter; in thick to massive resistant beds; cross-bedded with partings of shaly to platy sandstone and sandy mudstone, especially in the lower part; forms cliffs; lower contact transitional, but easily recognized where the slope-forming Masuk Shale Member is overlain by Tarantula Mesa Sandstone cliffs; about 200 feet (60 m) exposed in map area, but regionally 300+ feet (90+ m) thick.

Km Mancos Shale

Kmm Masuk Member (Upper Cretaceous, Campanian) – Sandy muddy shale, sandy carbonaceous shale, and muddy sandstone; moderately bentonitic; mostly gray, light-green-gray, and yellow-gray; sandstone increases upward and is very fine to fine grained, and contains some nodular and thin lenticular limestone beds; laminated to irregularly bedded; forms steep slope at base of Tarantula Mesa

Sandstone cliffs; contains petrified wood, shell fragments, and rare shark teeth; approximately 435 feet (135 m) thick.

Kmc Muley Canyon Sandstone Member

Kmcu Upper unit of Muley Canyon Sandstone Member (Upper Cretaceous, lower Campanian) – Sandstone, mudstone, carbonaceous mudstone and coal; sandstone is light to dark brown, fine to medium grained, in lenticular thin to massive beds, and commonly resistant; mudstone is gray, green gray, and yellow gray, laminated to thin bedded, slope forming, and locally bentonitic; carbonaceous mudstone is dark gray, medium to dark brown to black, laminated to thin bedded, and slope forming; coal is mostly in beds 3 to 4.5 feet (1-1.5 m) thick but locally as thick as 6 feet (2 m), high-volatile bituminous carbon, with Btu/lb values ranging from 7,700 to 10,800 and sulfur content from 0.5 to 3.5 percent (unpublished UGS data), cumulative average thickness for coal is about 7.1 feet (2.2 m); upper unit forms ledges and slopes; upper contact placed at top of uppermost thick, yellow-gray sandstone that forms a bench; contains plant impressions, plant debris, and sparse petrified wood; 65 to 180 feet (20-55 m) thick, variable because thick upper ledge not everywhere present.

Kmcl Lower unit of Muley Canyon Sandstone Member (Upper Cretaceous, lower Campanian) – Sandstone and sandy mudstone; mostly light to dark brown with a very light gray unit at top; very fine to medium grained, cross-bedded, thin to massive bedded, lenticular, generally cliff forming with a few sandy mudstone slopes; locally contains pyrite nodules that weather to limonite; trace fossils include *Ophiomorpha*, *Thalassinoides*, *Arenicolites*, and other tubes and burrows; 240 to 270 feet (70-85 m) thick.

Kmb Blue Gate Member (Upper Cretaceous, lower Campanian to Santonian) – Marine shale, mudstone, and siltstone; pale-blue-gray, slightly bentonitic; laminated to thin bedded, with several yellow-gray sandy beds that increase in number upward; weathers into low rolling hills and badlands, except under the lower unit of the Muley Canyon Sandstone Member cliffs where it stands as a recessed cliff or steep slope; 1200 to 1400 feet (365-425 m) thick.

-- *unconformity* (Coniacian missing) --

Kmf Ferron Sandstone Member

Kmfu Upper unit of Ferron Sandstone Member (Upper Cretaceous, upper to middle Turonian) – Sandstone, mudstone, carbonaceous mudstone, and coal; sandstone is light to dark brown, very fine to coarse grained, locally with chert pebbles; mudstone is gray, yellow gray, or green gray and commonly bentonitic, laminated to thin bedded; carbonaceous mudstone and shale is dark gray; coal is black, blocky and brittle, mostly in beds less than 2 feet (0.6 m) thick, high-volatile bituminous carbon, with Btu/lb values ranging between 10,000 and l1,000 and sulfur content ranging from 1 to 2.5 percent (unpublished UGS data); unit is slope and ledge forming with thicker ledges being more resistant; basal unit is poorly sorted, white or very light gray sandstone, mostly medium to coarse grained, and the upper surface displays abundant plant impressions; thin to massive lenticular beds; many units cross-bedded; 125 to 180 feet (38-55 m) thick, averages 155 feet (48 m).

Kmfl **Lower unit of Ferron Sandstone Member (Upper Cretaceous, upper to middle Turonian) –** Sandstone and mudstone; sandstone is mostly light to dark brown, very fine to medium grained, with rare coarse-grained lenses, and well to moderately sorted; sandstone commonly contains nodules of pyrite coated with limonite, and worm tracks and burrows; mudstone is gray to green gray and silty, quantity of mudstone decreases upward in section where it appears only as partings; unit grades downward into the Tununk Shale Member; lenticular and cross-bedded; generally forms a cliff; 110 to 255 feet (34-78 m) thick, averages 175 feet (53 m).

Kmt **Tununk Member (Upper Cretaceous, middle Turonian to upper Cenomanian) –** Marine shale, mudstone, sandy shale, and siltstone; medium- to dark-gray, becomes progressively sandier upward in section; bedding is mostly shaly to thin bedded, but is locally indistinct or medium bedded; forms steep slope under lower unit of Ferron Sandstone Member cliff and gently undulating low rounded hills in lower part; 525 to 650 feet (160-200 m) thick, averaging about 600 feet (180 m).

Kd **Dakota Sandstone (Upper Cretaceous, upper Cenomanian) –** Sandstone, conglomeratic sandstone, mudstone, carbonaceous mudstone, claystone, gray shale, and thin coal seams; sandstone is gray, yellow gray, and light brown, very fine to medium grained, in lenticular cross-stratified, discontinuous channels; conglomeratic sandstone and conglomerate occurs as lenses in the sandstone, pebbles and cobbles are dominantly quartzitic; mudstone is shades of gray, dependent on carbon content; claystone and gray shale have indistinct to thin beds and are locally bentonitic; coal seams are generally thin and lenticular, averaging less than a foot (0.3 m), but locally thicken to more than 4 feet (1.2 m); unit is ledgy, but with intervening slope-forming mudstones; generally fluvial deposition at base, then lagoonal, then marine; fluvial lithologies are locally missing; upper contact placed immediately above an interval of *Pycnodonte newberryi* fossils as prescribed by Lawyer (1972) and Peterson, Ryder, and Law (1980), but in some areas of the San Rafael Swell a local unconformity has been identified (Eaton and others, 1990); the more resistant sandstone and conglomeratic sandstones occur throughout the unit, but are generally associated with the lower third; claystones and gray shale units form slopes and occur mostly near the base and top of the unit; the mudstones and carbonaceous mudstones are generally in the middle and form steep slopes; some clay is classed as high- or super-duty refractory; sandstones and conglomeratic sandstone beds at base commonly form a thick ledge, lagoonal beds form a steep slope over the ledge that ends with the *Pycnodonte newberryi* zone, the steep slope being more resistant than overlying Tununk shale beds; some sandstones contain large fossil oysters and exhibit burrows, chevron trails and labyrinth casts; 20 to 170 feet (6-52 m) thick.

-- unconformity --

Kcm Cedar Mountain Formation (Lower Cretaceous, Albian to Barremian) – Mudstone, shale, muddy sandstone, conglomerate and conglomeratic sandstone, calcareous nodules, and muddy siltstone; gray, gray-brown, lavender, green-gray, and red; sandstones are commonly cross-bedded; mudstones are commonly bentonitic and form a smooth, commonly banded slope; base in some areas is a conglomeratic sandstone ledge known as the Buckhorn Conglomerate (not mapped); where Buckhorn is missing, unit is difficult to separate from the Brushy Basin Member of the Morrison Formation below; contains dinosaur bones, gastroliths, petrified wood, other plant fragments, local fresh-water shellfish, ostracodes, ganoid fish scales, and charophytes; has been divided into several members including Buckhorn Conglomerate, Yellow Cat, Poison Strip Sandstone, Ruby Ranch, and Mussentuchit by Kirkland (2005) (not mapped here due to scale constraints); unit dated by Kirkland (2005) as Lower Cretaceous (Barremian to Albian); 80 to 120 feet (24-37 m) thick.

KJu Cretaceous and Jurassic units undifferentiated (Lower Cretaceous and Upper Jurassic) – Mudstone, shale, and bentonitic siltstone resembling Kcm and Jmb, but mixed together and indistinguishable in slumps and landslides; mapped only near Hens Hole Peak in northwest part of map (Qms[KJu]); varied thickness.

--K-0 unconformity--

Jm Morrison Formation

Jmb Brushy Basin Member (Upper Jurassic, Tithonian) – Mostly bentonitic siltstone and mudstone with local friable fine- to coarse-grained sandstone, conglomeratic sandstone, and conglomerate; colors alternate as bands in shades of lavender, purple, brown, and red, but light-gray dominates; locally contains siliceous and calcareous, brown-weathering nodules; coarser units are lenticular, discontinuous, cross-bedded, and quartzitic; appears like the Cedar Mountain Formation that overlies it, but colors are generally more vivid; generally forms smooth slopes with some ledges that support little or no vegetation; locally contains silicified wood and bone fragments; grades downward into the Salt Wash Member; upper contact is an unconformity that is difficult to recognize, and some previous investigators have elected to map the Brushy Basin Member with the overlying Cedar Mountain Formation (Smith and others, 1963); 70 to 200 feet (20-60 m) thick, averaging 150 feet (45 m), roughly thickening northwestward.

Jms Salt Wash Member (Upper Jurassic, Kimmeridgian) – Sandstone, conglomeratic sandstone, siltstone, and claystone; sandstone and conglomeratic sandstone is mostly light gray, with areas of gray-pink, pale-red, and yellow-gray, very fine grained to very coarse grained, angular to subrounded, pebbles and cobbles in conglomerate are generally chert with lesser quartzite and silicified limestone; beds lenticular, cross-bedded, channel-form, and resistant; siltstone and claystone are commonly red or green gray and form recesses between thick channels of sandstone; unit dominated by ledges that commonly collapse and form rubble over the softer slope-forming units; locally contain dinosaur bone fragments and silicified wood; lower beds channeled into the Tidwell Member below; channel sandstones are locally uraniferous, and contain clay galls and rip-ups in the base; 50 to 280 feet (15-85 m) thick, averaging 184 feet (56 m), roughly thickening southeastward.

Jmt Tidwell Member (Upper Jurassic, Kimmeridgian and uppermost Oxfordian) – Siltstone, sandstone, mudstone, gritstone, and gypsum; finer grained clastic units are generally red or gray green in crinkly thin beds; coarser units are lenticular, cross-bedded, and more resistant than finer grained units; gypsum is common as a thick alabaster bed at the base of the member, but the bed is discontinuous and not everywhere present; secondary gypsum veinlets commonly crisscross within the beds and lenses; unit forms a slope or recess beneath the Salt Wash Member ledges; 30 to 110 feet (9-34 m) thick, averaging 55 feet (17 m), with thicker sections northward.

-- J-5 unconformity --

Js Summerville Formation (Middle Jurassic, Callovian) – Siltstone, mudstone, and fine-grained sandstone; light- to medium-red-brown (milk-chocolate brown), in mostly thin even beds; calcareous; gypsum occurs in crisscrossing veinlets and very thin beds; locally contains red-encrusted white nodules and blebs of crystalline quartz and calcite; generally forms an earthy slope with a few fine-grained sandstone ledges that become more prevalent toward the top and that are commonly rippled and cross-bedded; 140 to 260 feet (40-80 m) thick, thinning irregularly southward.

Jct Curtis Formation (Middle Jurassic, Callovian) – Sandstone and subordinate siltstone; light- to medium-gray, gray-green, and white; fine-grained- to medium-grained; grain size decreases upward; grains are dominantly quartz, glauconitic, muddy (argillaceous), and calcareous; thin- to thick-bedded to indistinctly bedded; in northern areas forms a lower knobby cliff and upper earthy slope, in southern areas mainly forms an earthy slope with thin ledges; a hard, medium bed of light-gray, coarse-grained sandstone is commonly displayed at base that is cross-bedded and locally has a pebble conglomerate at the base; locally contains concretionary siliceous and carbonate horizons; thickness 10 to 220 feet (3-67 m) thick, generally increasing northward, but locally changing erratically along outcrop.

-- J-3 unconformity --

Je
Jem **Entrada Sandstone (Middle Jurassic, Callovian) –** Sandstone with subordinate interbedded siltstone and claystone; mostly red-orange, red-brown, and white, with subordinate purple, yellow, and brown; mostly fine- to very fine grained, with scattered coarse, subangular to subrounded, mostly well sorted grains; commonly cross-bedded; outcrops range from soft and earthy weathering to hard and cliffy; commonly covered with large tracts of self-derived eolian sand; has been divided into lower, middle, and upper members (not on this map) by some previous investigators (for example Wright and Dickey, 1980); prominent sandstone marker bed (Jem) is locally mapped and represents the top of the middle member; 650 to 800 feet (200-245 m) thick.

Jc **Carmel Formation**

Jcw **Winsor Member**

Jcwb **Banded unit (Middle Jurassic, Callovian and Bathonian) –** Interbedded siltstone, sandstone, mudstone and thin gypsum beds arranged in irregular cyclic fashion; mostly light-gray or light-brown-gray with subordinate red or red-brown bands; many mudstone and siltstone beds are crisscrossed with secondary gypsum veinlets; forms slopes with thin gypsum ledges; conformable with unit below; 120 to 450 feet (37-137 m) thick, thinning eastward.

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Jcwg **Gypsiferous unit (Middle Jurassic, Bathonian) –** Thick alabaster gypsum beds interbedded with subordinate red and light-gray siltstone to fine-grained sandstone beds; conformable with unit below; forms rounded cliffs and steep slopes (more resistant than overlying Banded unit); 80 to 230 feet (24-70 m) thick, thinning eastward.

Jcpr **Paria River Member (Middle Jurassic, Bathonian) –** Calcarenite and limestone; light-gray and yellow-gray, sandy and silty, locally includes a thick alabaster gypsum bed at base; also has subordinate red-brown, slope-forming, calcareous siltstone layers and light-yellow-gray sandstone beds; thin- to medium-bedded; weathers platy to pencilly and forms ledges and slopes; conformable with unit below; 100 to 220 feet (30-67 m) thick, thinning eastward.

Jcpc **Page Sandstone, Co-op Creek Limestone, and Crystal Creek Members of the Carmel Formation (new usage – Page Sandstone formerly considered a separate formation; we herein informally treat it as a member of the Carmel Formation) (Middle Jurassic, Bathonian and Bajocian) –** Sandstone; yellow-gray or light-gray in eastern exposures; interbedded with red-brown siltstone, gray limestone, yellow-gray calcarenite, and medium-gray mudstone in western exposures; secondary gypsum and a few gypsum beds locally present; sandstones and calcarenites are mostly fine grained and most beds are calcareous; forms a series of thick ledges or cliffs; commonly a sandstone ledge or cliff is at the base; Page consists primarily of eolian cross-bedded sandstone; map unit consists of eolian sandstone (Jones and Blakey, 1993) (Harris Wash Tongue of Page), overlain by calcarenite and limestone (Co-op Creek Limestone), then red siltstone (Crystal Creek Member), and an upper sandstone ledge or cliff (Thousand Pockets Tongue of Page) (member names from southern Utah - see for example Doelling and Davis, 1989); locally fossiliferous in western exposures; 50 to 200 ft (15-60 m) thick, thinning eastward; lower contact is a disconformity with moderate relief so that the thickness of the lower sandstone ledge or cliff fluctuates.

-- J-2 unconformity --

Jn Navajo Sandstone

Jn Main body (Lower Jurassic) – Sandstone; mostly pale-yellow-gray, pale-gray, or very pale orange, fine- to medium-grained, well-sorted, subrounded to subangular, friable, contains scattered dark mineral grains; cross-bedded in large trough sets that are locally deformed by soft-sediment slumping; mostly massive sets separated by long even surfaces that bevel underlying cross-beds; weathers into domes and rounded knolls; intertongues with Kayenta Formation below; lower contact placed above conspicuous 5- to 10-foot- (2-3 m) thick red-brown tongue of Kayenta Formation that forms slope or recess (see Jnl); estimated thickness is 800 to 1100 feet (240-330 m), thickening westward; 800 to 900 feet (240-300 m) along Waterpocket Fold and 1000 to 1100 feet (310-330 m) around Boulder Mountain (Smith and others, 1963).

Jnl Lower tongue (map unit includes thin tongue of Kayenta Formation) (Lower Jurassic) – Sandstone; mostly pale-gray to pale-orange like that of the main body, but locally red; red coloration probably due to staining from Kayenta tongue above; has 5 to 10 feet (2-3 m) red-brown, silty and muddy, fine- to medium-grained sandstone at top that forms recess or steep slope that is part of the Kayenta Formation, but is not mapped separately; represents massive, cliffy tongue of Navajo Sandstone in the upper part of the Kayenta Formation; grades into Kayenta Formation below; 110 to 150 feet (34-46 m) thick.

Jk Kayenta Formation (Lower Jurassic) – Interbedded sandstone, siltstone, and intraformational conglomerate; sandstone is pink gray, red brown, or yellow gray, mostly very fine to fine grained, somewhat calcareous, hard to friable, commonly cross-bedded, mostly thick bedded to massive (some lenticular with rip-up clasts in base), cliff- or ledge-forming; siltstone is medium to dark red brown, commonly cemented with iron oxides and calcite, muddy, generally present as partings and thin beds between sandstone units, forms indentures, recesses, and slopes; intraformational conglomerate is light brown overall, pebbles to 1 inch (3 cm) diameters and generally composed of sandstone, forms hard ledges, calcareous, cross-bedded; overall unit forms series of ledges; grades into Wingate Sandstone over an interval of about 20 feet (6 m); 150 to 220 feet (46-67 m) thick.

JTRw Wingate Sandstone (Lower Jurassic to Upper Triassic) – Sandstone, orange-brown and red-brown, locally bleached to yellow-gray; fine-grained, massive, grains subangular to rounded and frosted, quartzose; forms vertical sheer cliffs along canyon walls that are commonly stained with manganese oxide (desert varnish); contains local partings of sandy siltstone that are more common near the base; mostly high-angle cross-bedded interlayered with planar beds; generally well cemented with calcium carbonate and iron oxides, but locally siliceous; contact with Chinle below is generally abrupt and placed at the base of the cliff; 300 to 400 feet (90-120 m) thick; two direct measurements made of 330 and 340 feet (100 and 104 m).

--unconformity (J-0 of Pipiringos and O'Sullivan, 1978). The Jurassic Triassic boundary is now widely believed to lie within the Wingate Sandstone (Molina-Garza and others, 2003; Lucas and others, 2006)--

TRc **Chinle Formation**: 435 to 600 ft (130-185 m) thick. Upper Triassic.

TRcu Upper slope former (approximately equivalent to Owl Rock Member) (Upper Triassic) – Siltstone, sandstone, mudstone, and subordinate limestone; individual bed colors include light-gray-green, lavender, light-gray-brown, red-brown, light-gray, lavender-brown, lavender-gray, and pale-red, and overall appearance is pale red brown; unit forms a steep slope with slight ledges beneath the Wingate Sandstone cliff that is commonly littered with sandstone; siltstone generally breaks into small equidimensional fragments; bedding is shaly to obscure and forms slopes; sandstone is generally lavender brown, fine to medium grained, friable, calcareous, and forms slight ledges or slopes; mudstone is green gray to red brown and silty; limestone is present in thin beds or nodular zones and is lavender gray; 140 to 220 feet (43-67 m) thick.

TRcl Lower slope former (approximately equivalent to the Petrified Forest Member but may also include the Mossback Member) (Upper Triassic) – Interbedded sandstone, siltstone, mudstone, and claystone; mostly slope forming with overlying ledge of sandstone, conglomeratic sandstone, and conglomerate that may be the Mossback Member; upper contact placed above ledge; slope is alternating lavender red, red brown, or green gray, ledges in slope are thin and inconspicuous, contains numerous fossil soil horizons; commonly micaceous, concretionary, and with buried logs of petrified wood; upper ledge is cliffy, cross-bedded and channeled into slope below, also contains petrified wood; unit is commonly difficult to distinguish from upper part of the Monitor Butte Member below; 90 to 190 feet (27-58 m) thick; differences in thickness partially due to variable placement of lower contact.

TRcm Monitor Butte Member (Upper Triassic) – Sandstone, siltstone, and muddy claystone, medium-gray and green-gray with subordinate lavender, gray-red, and yellow-gray; locally contains petrified wood; forms rounded ledges and slopes; sandstone mostly medium-grained (some fine-grained), medium to poorly sorted; mixed lithology gives "salt-and-pepper" appearance; thin-bedded and platy to ledgy, crumbly and darker than Shinarump Member sandstone beneath; siltstone weakly cemented, calcareous, with indistinct bedding, commonly contains silty calcareous nodules, weathers into frothy rubble-covered slopes; claystones silty and sandy, uncommonly bentonitic, mostly poorly exposed and slope-forming; lower contact sharp in most cases; 110 to 190 feet (34-58 m) thick.

TRcs Shinarump Member (Upper Triassic) – Sandstone, light-gray, yellow-gray, and white, fine- to coarse-grained, trough cross-bedded; some conglomeratic lenses and scattered pebbles, bedded lenticularly with lenses as much as 12 feet (3.5 m) thick; contains a few partings of muddy sandstone as much as 4 inches (10 cm) thick; porous; slightly calcareous; resistant and cliff-forming; discontinuous and channeled into Moenkopi Formation below (not obvious in many places); 0 to 145 feet (0-44 m) thick.

-- TR-3 unconformity --

TRm Moenkopi Formation (Lower Triassic) – 625 to 990 feet (190-300 m) thick.

TRmm Moody Canyon Member (Lower Triassic) – Mudstone, claystone, siltstone, and very fine grained sandstone; medium- to dark-red-brown; interrupted intermittently by yellow-gray, fine-grained, sandstone that is platy and slightly more resistant than red-brown siltstone; micaceous, contains crisscrossing veinlets, thin beds, and lozenges of gypsum; thin- to medium-bedded with local thick beds; commonly ripple-marked; forms steep slope and recessed cliff under Shinarump Member; less resistant than unit below; conformable with Torrey Member below; 260 to 425 feet (80-130 m) thick, thickening westward.

TRmt Torrey Member (Lower Triassic) – Sandstone, siltstone, and mudstone; mostly medium-red-brown (chocolate-brown) with widely spaced yellow-brown ledges; siltstones and mudstones are generally medium to dark red brown; sandstone is medium to very fine grained; mostly calcareous; units are commonly cross-bedded and ripple-marked; forms ledges and slopes; 250 to 320 feet (76-98 m) thick, thickening westward.

TRms Sinbad Limestone Member (Lower Triassic) – Limestone, dolomite, and dolomitic limestone with subordinate calcareous sandstone and siltstone; light-gray, gray-brown, yellow-brown; crystalline and clastic (much is calcarenite); some limestone is oolitic and beds are locally stylolitic; thin- to thick-bedded (2 inches to 3 feet [5 cm-1 m] thick); conspicuously jointed; forms prominent resistant ledge or cliff; weathers hackly; conformable with the Black Dragon Member below; contains rare gastropod, pelecypod, and ammonite fossils; 60 to 120 feet (18-37 m) thick, thickening westward.

TRmb Black Dragon Member (Lower Triassic) – Siltstone and very fine grained sandstone; much is muddy; mostly red brown, except for a few feet at base and top where it is light yellow gray; forms steep slope; has local thin (as much as 15 feet [5 m] thick) basal conglomerate with angular pebbles and cobbles derived from the Kaibab Limestone below; lower contact is a regional unconformity; 55 to 125 feet (17-38 m) thick, thickening westward.

--TR-1 unconformity--

Pk **Kaibab Limestone (Lower Permian) –** Limestone, limy dolomite, and dolomite; crystalline and calcarenite; impure and cherty, with subordinate sandstone and local gray shale; limestone, limy dolomite, and dolomite beds are mainly white, light gray, and yellow gray, and locally yellow brown; weathers hackly; chert is present in light-gray thin beds, nodules, or as small geodes whose interiors are commonly lined with small quartz crystals; some carbonate beds are sandy and cross-bedded, others chalky; beds are thin to massive (a few inches to 8 feet thick [5 cm-2.5 m]), resistant and cliff forming; sandstone is generally gray to brown, calcareous, and fine to medium grained, locally exhibiting high-angle cross-bedding; local shale lenses are gray and soft; locally contains poorly preserved marine fossils including brachiopods, pelecypods, gastropods, bryozoans, and crinoid stems; locally petroliferous, especially along east side of Miners Mountain; contact between Cedar Mesa Sandstone and Kaibab is transitional and selected at lowest thick limestone; 300 to 400 feet (91-122 m) thick, differences in thickness may be related to relief on upper unconformity.

Pcm **Cedar Mesa Sandstone (includes White Rim Sandstone that is not divided out because the Organ Rock Shale is not present) (Lower Permian) –** Sandstone, yellow-gray, light-yellow-brown, weathering light-brown, fine- to medium-grained, well-rounded and frosted, well-sorted and quartzose; massive; exhibits high-angle cross-beds in wedge-shaped lenses; calcareous and siliceous cement; somewhat porous; weathers by exfoliation; resistant, forms cliffs and steep slopes broken by silty partings; maximum of about 630 feet (192 m) exposed, base not exposed.

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(numbers refer to index map on plate 1)

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Title block:

Interim Geologic Map of the East Half of the Loa 30' x 60' Quadrangle, Wayne, Garfield and Emery Counties, Utah

by

Hellmut H. Doelling and Paul Kuehne

2007

Upper right:
Plate 1
Utah Geological Survey Open-File Report 489
Interim Geologic Map of the East Half of the Loa 30' x 60' Quadrangle

Lower right:
Project Managers: Donald L. Clark and Grant C. Willis
Digital Cartography: Buck Ehler, Darryl Greer, and Paul Kuehne

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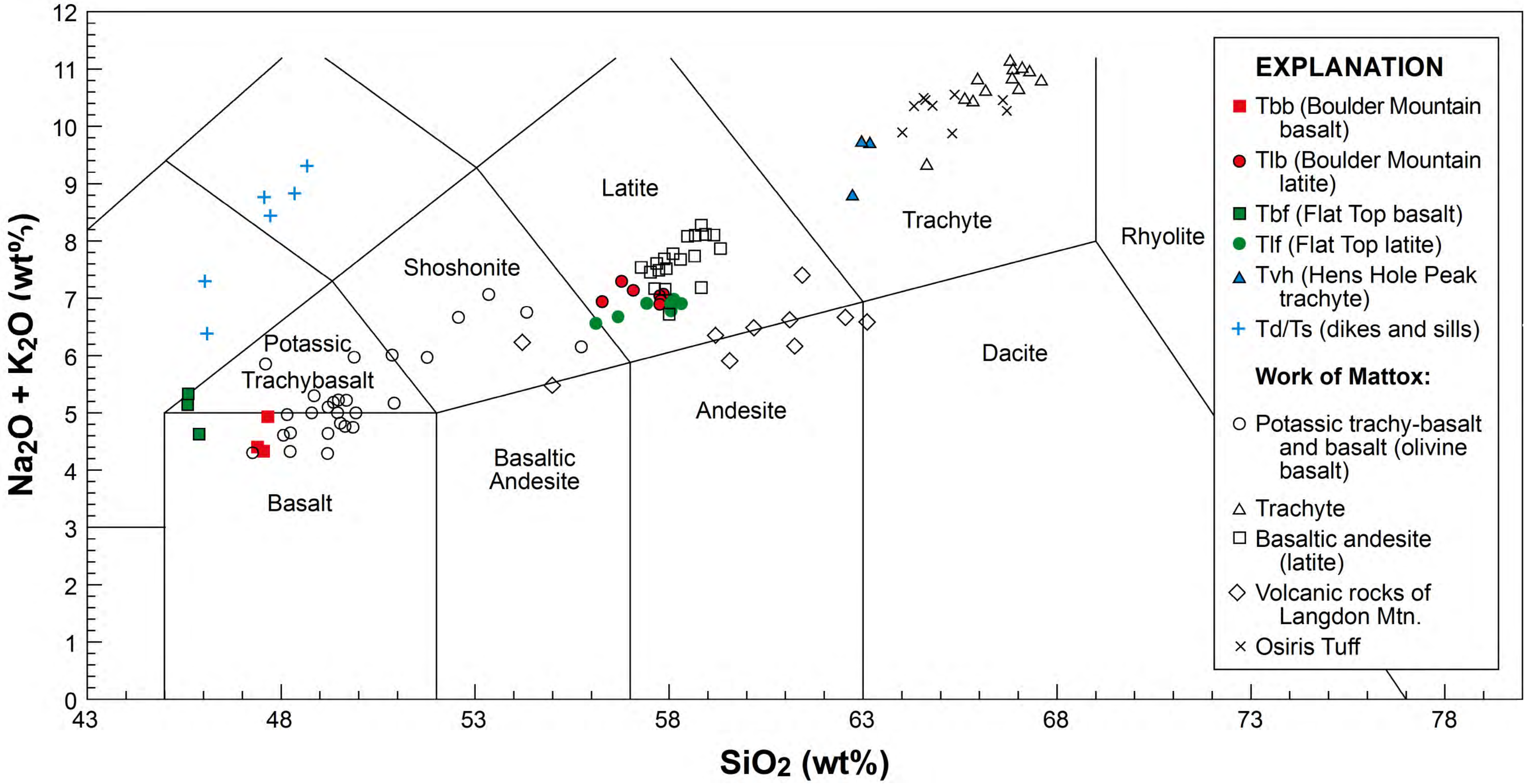


Figure 1: Total Alkali Silica (TAS) diagram; Data from Mattox, 1991 are samples taken west of the Loa 30′ X 60′ quadrangle on the Awapa Plateau; Dike and sill samples were taken from Mussentuchit Wash and Hebes Mountain in the Salina 30′X60′ quadrangle (Doelling, 2004) north of the Loa 30′X60′ quadrangle in the same system of dikes.

Table 1. Major and trace element whole-rock analyses.

Rock Name		Basalt	Basalt	Basalt	Basalt	Latite	Latite	Latite	Latite	Latite
Sample #		BT091106-2	FT091306-3	FT091306-4	FT091306-6	BM081605-1	BM081605-2	BM091206-3	BM091206-4	BM091206-5
Map Symbol		Tbb	Tbf	Tbf	Tbf	Tlb	Tlb	Tlb	Tlb	Tlb
7.5' Quadrangle		Blind Lake	Flat Top	Flat Top	Flat Top	Deer Creek Lake	Deer Creek Lake	Deer Creek Lake	Deer Creek Lake	Deer Creek Lake
Latitude (N)		38°09' 20.8"	38°25' 07.6"	38°24' 48.2"	38°25' 01.2"	38°09.716'	38°05.557'	38°06' 56.5"	38°05' 38.2"	38°05' 45.3"
Longitude (W)		111°29' 55.1"	111°29' 21.9"	111°29' 31.0"	111°28' 42.2"	111°23.866'	111°24.766'	111°26' 18.7"	111°24' 42.9"	111°24' 39.2"
SiO2	%	44.59	46.23	46.82	46.73	56.76	57.08	55.95	55.75	56.57
Al2O3	%	14.71	15.39	15.45	16.14	1.06	1.06	17.36	16.21	17.17
Fe2O3	%	10.38	10.75	10.87	10.94	16.84	16.81	8.43	7.85	8.24
CaO	%	9.74	10.24	10.35	9.94	8.14	8.22	5.5	5.29	5.56
MgO	%	10.65	8.29	8.33	7	0.12	0.13	2.58	3.07	3.07
Na2O	%	2.49	2.62	2.84	3.1	2.83	2.9	3.68	3.38	3.6
K2O	%	2.01	1.68	1.42	1.73	5.41	5.34	3.51	3.41	3.46
Cr2O3	%	0.07	0.04	0.04	0.04	3.35	3.45	0.01	<0.01	0.02
TiO2	%	1.8	1.54	1.58	1.65	3.42	3.5	1.04	0.98	1.01
MnO	%	0.17	0.16	0.16	0.16	0.38	0.39	0.12	0.11	0.12
P2O5	%	0.64	0.7	0.71	0.74	<0.01	<0.01	0.38	0.37	0.38
SrO	%	0.1	0.18	0.19	0.18	0.08	0.08	0.09	0.08	0.09
BaO	%	0.2	0.21	0.2	0.2	0.08	0.08	0.08	0.08	0.08
LOI	%	1.72	1.15	0.99	0.49	1.26	0.98	1.12	1.64	0.61
Total	%	99.26	99.19	99.96	99.04	99.74	100	99.85	98.23	99.98
Ag	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ba	ppm	1715	1770	1695	1725	734	777	668	729	667
Ce	ppm	115.5	154	155.5	162.5	91.4	103.5	87.3	96	89.1
Co	ppm	46.3	45.2	46.2	41.8	23.4	25.3	22.4	23.5	22.3
Cr	ppm	430	320	320	220	70	60	30	30	40
Cs	ppm	3.06	0.45	0.52	0.43	3.7	4.6	3.44	4.43	3.82
Cu	ppm	48	51	60	53	106	113	133	125	113
Dy	ppm	5.33	4.03	3.88	4.19	4.8	5.1	4.81	4.85	3.75
Er	ppm	3.01	2.49	2.45	2.53	2.7	2.9	2.86	2.89	2.48
Eu	ppm	2.55	2.51	2.53	2.73	1.9	2	1.91	1.91	1.59
Ga	ppm	16.2	18.4	18.1	19.3	23	23	20.6	22.7	19.7
Gd	ppm	7.33	8.43	8.41	8.75	7.1	7.6	6.46	7.25	6.42
Hf	ppm	6.1	4.9	4.7	4.7	6	7	6.8	6.7	6.4
Ho	ppm	1.01	0.85	0.84	0.85	0.9	1	0.94	0.91	0.85
La	ppm	55	77.6	77.6	80.3	45.9	51.4	42	46.4	44.8
Lu	ppm	0.37	0.28	0.27	0.26	0.4	0.4	0.36	0.36	0.33
Mo	ppm	2	2	<2	<2	3	3	2	2	3
Nb	ppm	49.4	25.6	25.2	24.6	11	12	10.6	11.4	11.2
Nd	ppm	52.9	72.7	70.8	75	43.1	48.3	42.5	45.5	42.5
Ni	ppm	240	159	163	115	20	19	20	20	18
Pb	ppm	6	12	12	11	28	22	19	19	20
Pr	ppm	13.55	19	19.05	19.7	11.4	12.8	10.55	11.55	11.05
Rb	ppm	88.9	26.6	30.6	26.7	122.5	134	123.5	125	105
Sm	ppm	8.5	10.7	10.45	10.75	8.1	8.9	7.64	8.27	7.64
Sn	ppm	1	1	1	1	2	2	2	2	2
Sr	ppm	973	1620	1675	1590	858	846	861	807	771
Ta	ppm	2.6	1.4	1.4	1.4	0.7	0.8	0.7	0.7	0.8
Tb	ppm	1	1.05	0.98	1.04	0.9	1	0.95	0.99	0.83
Th	ppm	4.76	4.82	4.86	4.94	16	18	16.3	17.6	18.05
Tl	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Tm	ppm	0.39	0.33	0.33	0.35	0.3	0.4	0.39	0.35	0.37
U	ppm	1.15	0.93	0.84	1.01	5.3	6.3	5.35	6.05	5.5
V	ppm	237	224	229	234	235	233	229	202	193
W	ppm	2	3	2	2	4	3	5	3	3
Y	ppm	26.8	25.1	23.4	24.1	26.9	28.8	24.8	25.5	23.7
Yb	ppm	2.55	2.04	1.94	2.04	2.4	2.7	2.6	2.49	2.32
Zn	ppm	97	98	98	102	82	87	94	97	82
Zr	ppm	219	200	195	200	202	231	216	230	222

Notes:

Major oxides reported in weight percent by x-ray flurescence (XRF); minor and major trace elements reported in ppm by inductively coupled plasma-mass spectrometry (ICP-MS).

All analysis performed by ALS Chemex Labs, Inc., Sparks, NV

Rock name using TAS diagram of Le Bas and others (1986).

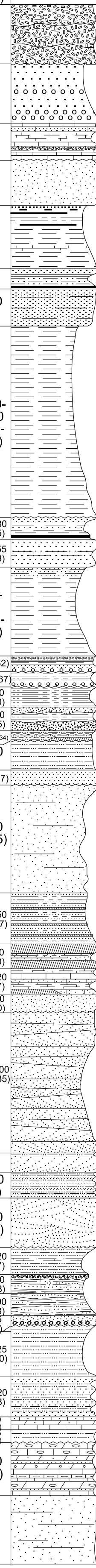
Rock Name		Latite	Latite	Trachyte	Trachyte	Latite	Latite	Latite	Latite	Latite
Sample #		BM091206-6	BT091106-3	HH091406-5	HH091406-4	DP091206-1	FT081505-1	FT081505-2	FT091306-1	FT091306-5
Map Symbol		Tlb	Tlb	Tvh	Tvh	Tlb	Tlf	Tlf	Tlf	Tlf
7.5' Quadrangle		Deer Creek Lake	Blind Lake	Flat Top	Flat Top	Blind Lake	Flat Top	Flat Top	Flat Top	Flat Top
Latitude (N)		38°05' 43.5"	38°09' 47.1"	38°29' 19.7"	38°29' 05.7"	38°10' 39.5"	38°26.462'	38°26.312'	38°26' 27.9"	38°24' 48.2"
Longitude (W)		111°24' 39.8"	111°29' 50.0"	111°28' 36.2"	111°28' 21.3"	111°27' 05.5"	111°28.750'	111°28.293'	111°28' 15.2"	111°29' 31.0"
SiO2	%	56.2	55.88	64.2	62.44	55.62	57.34	57.25	56.99	57.3
Al2O3	%	16.73	17.06	16.22	18.36	17.07	1.05	1.03	17.15	16.66
Fe2O3	%	7.74	8.07	4.74	3.55	8.64	16.59	16.79	8.17	8.16
CaO	%	5.56	5.58	1.72	2.97	5.75	8.08	8	5.2	5.34
MgO	%	2.85	2.72	0.76	0.97	3.37	0.12	0.12	2.58	2.7
Na2O	%	3.45	3.58	4.01	3.95	3.57	2.73	3.08	3.42	3.41
K2O	%	3.31	3.4	5.97	5.68	3.3	5.33	5.27	3.25	3.48
Cr2O3	%	<0.01	0.01	<0.01	0.02	<0.01	3.31	3.37	0.02	<0.01
TiO2	%	0.98	1.1	0.85	0.79	1.06	3.49	3.45	1	1.05
MnO	%	0.12	0.12	0.09	0.05	0.13	0.39	0.4	0.12	0.13
P2O5	%	0.36	0.39	0.27	0.18	0.38	<0.01	<0.01	0.39	0.38
SrO	%	0.09	0.09	0.03	0.09	0.09	0.07	0.07	0.08	0.08
BaO	%	0.08	0.08	0.11	0.16	0.08	0.07	0.07	0.07	0.08
LOI	%	1.38	0.92	0.81	0.51	0.09	1.15	0.74	1.61	1.23
Total	%	98.85	99.01	99.78	99.73	99.15	99.7	99.64	100.05	100
Ag	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ba	ppm	712	703	934	1380	713	678	657	605	640
Ce	ppm	92.6	85.2	126.5	121	94.3	102	94.8	85.2	92.3
Co	ppm	23.7	21.4	5.9	5.8	23	23	22	21.2	23.5
Cr	ppm	30	30	<10	30	30	50	70	30	50
Cs	ppm	4.34	3.21	6.51	7.8	3.44	4.4	4.2	3.44	4.09
Cu	ppm	142	123	22	16	134	100	101	103	116
Dy	ppm	4.71	4.66	5.25	3.42	4.79	6.9	5.6	4.35	4.64
Er	ppm	2.69	2.67	3.26	2.37	2.8	3.6	3.2	2.75	3.01
Eu	ppm	1.96	1.88	1.76	1.94	1.97	2.4	1.9	1.73	1.77
Ga	ppm	23.4	20.2	19.9	20.7	21.8	23	23	21	20.9
Gd	ppm	7.07	6.25	8.1	6.66	6.59	9.7	8.1	6.78	7.06
Hf	ppm	6.3	6.3	9.9	10.2	6.9	7	7	6	6.7
Ho	ppm	0.88	0.89	1.03	0.75	0.93	1.3	1.1	0.98	0.96
La	ppm	44.5	41.4	64.6	65.2	45.3	61	47.6	42.7	44.6
Lu	ppm	0.34	0.36	0.48	0.32	0.37	0.5	0.4	0.37	0.4
Mo	ppm	2	2	4	3	2	3	3	2	2
Nb	ppm	10.7	10	17.9	24.5	11.2	13	13	11.9	12.4
Nd	ppm	43.7	41	56	49.1	45	57.8	47.3	42.6	45.4
Ni	ppm	21	20	<5	5	22	17	16	14	24
Pb	ppm	19	18	30	25	20	27	28	17	17
Pr	ppm	11.15	10.15	15.3	13.9	11.15	15.3	12.2	10.95	11.9
Rb	ppm	114.5	117	201	216	109.5	134	132.5	117.5	122.5
Sm	ppm	8.16	7.24	9.56	8.27	8.09	10.7	8.9	8	8.33
Sn	ppm	2	2	3	2	2	2	2	2	2
Sr	ppm	875	865	290	717	934	733	725	686	655
Ta	ppm	0.7	0.6	1.3	1.8	0.7	0.8	0.9	0.8	0.9
Tb	ppm	0.95	0.9	1.06	0.84	0.93	1.3	1	0.94	1
Th	ppm	16.9	15.4	27	39.1	16.25	16	16	14.15	15.95
Tl	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Tm	ppm	0.34	0.35	0.52	0.35	0.38	0.5	0.4	0.4	0.43
U	ppm	5.66	4.94	8.02	11.6	5.32	5.1	5.3	4.32	4.52
V	ppm	212	208	43	56	211	224	201	172	203
W	ppm	3	3	5	5	4	3	3	4	5
Y	ppm	24.3	23.4	29.8	21.2	25.8	35.5	32.4	27.6	28.2
Yb	ppm	2.38	2.48	3.13	2.22	2.64	3.2	2.9	2.69	2.63
Zn	ppm	94	93	71	53	104	85	85	85	86
Zr	ppm	214	205	357	398	227	231	235	222	229

Rock Name		Latite	Latite	Latite	Latite	Potassic Trachybasalt	Potassic Trachybasalt	Trachyte	Trachyte
Sample #		FT091306-7	HH091406-1	HH091406-6	HL091206-2	BT091106-1	BT091106-4	HH091406-2	HH091406-3
Map Symbol		Tlf	Tlf	Tlf	Tlb	Tlb	Tlb	Tvh	Tvh
7.5' Quadrangle		Flat Top	Flat Top	Flat Top	Deer Creek Lake	Blind Lake	Blind Lake	Flat Top	Flat Top
Latitude (N)		38°25' 24.8"	38°29' 06.7"	38°28' 35.3"	38°05' 07.6"	38°09' 34.3"	38°10' 0.9"	38°29' 05.0"	38°29' 05.7"
Longitude (W)		111°28' 07.6"	111°28' 15.3"	111°28' 09.8"	111°27' 39.7"	111°29' 57.4"	111°29' 51.4"	111°28' 17.7"	111°28' 21.3"
SiO2	%	56.1	56.45	55.45	56.04	44.89	45.28	61.05	60.01
Al2O3	%	16.73	16.82	16.96	17.2	14.75	14.97	16.44	17.81
Fe2O3	%	8.87	8.17	8.67	8.31	10.61	10.7	4.53	3.64
CaO	%	5.98	5.56	6.17	5.56	9.97	9.93	2.51	3.32
MgO	%	3.15	2.95	3.54	2.89	10.61	10.42	1.74	1.45
Na2O	%	3.5	3.45	3.47	3.6	3.01	3.1	3.84	3.36
K2O	%	3.11	3.38	3.03	3.6	2.07	2.19	5.62	5.06
Cr2O3	%	0.01	0.01	0.01	0.01	0.06	0.06	<0.01	<0.01
TiO2	%	1.08	1.08	1.03	1.03	1.51	1.63	0.84	0.81
MnO	%	0.13	0.13	0.13	0.13	0.18	0.18	0.1	0.06
P2O5	%	0.37	0.39	0.36	0.39	0.92	0.93	0.29	0.18
SrO	%	0.08	0.08	0.09	0.09	0.15	0.14	0.06	0.09
BaO	%	0.08	0.07	0.08	0.08	0.25	0.25	0.13	0.15
LOI	%	0.83	1.31	0.51	0.98	-0.01	0.21	2	3.6
Total	%	100	99.86	99.5	99.91	98.97	100	99.15	99.53
Ag	ppm	<1	<1	<1	<1	<1	<1	<1	<1
Ba	ppm	640	614	686	688	2210	2110	1140	1270
Ce	ppm	80.4	84.4	82.6	93.2	180	169	123.5	120
Co	ppm	25.4	21.4	25	21.5	47.7	46.4	5.6	6
Cr	ppm	50	30	60	40	380	390	10	10
Cs	ppm	2.38	4.74	2.63	4.23	3.48	3.55	1.58	8.92
Cu	ppm	116	97	115	132	48	49	16	18
Dy	ppm	4	4.51	4.44	5.05	5.86	6.04	4.95	3.67
Er	ppm	2.65	2.89	2.6	2.8	3.32	3.37	2.93	2.21
Eu	ppm	1.62	1.72	1.65	1.95	3.15	3.24	1.96	1.81
Ga	ppm	19.9	20.6	21.4	20.9	17.6	17.3	20	19.3
Gd	ppm	6.29	6.76	6.33	6.72	9.34	9.45	7.88	6.49
Hf	ppm	5.8	5.8	5.9	7.2	5.8	6.4	8.6	9.9
Ho	ppm	0.85	0.97	0.88	0.91	1.08	1.14	0.96	0.73
La	ppm	39.6	41.8	40.1	45.5	89	83.8	63.3	64.3
Lu	ppm	0.35	0.39	0.33	0.38	0.4	0.41	0.41	0.28
Mo	ppm	2	2	2	2	2	2	2	3
Nb	ppm	10.5	11.3	10.6	11.3	50.1	54.6	15.4	24.2
Nd	ppm	40	42.8	40.4	44.9	77.5	73.9	55.6	48.5
Ni	ppm	21	15	20	20	252	243	<5	6
Pb	ppm	15	16	16	19	7	9	25	25
Pr	ppm	10.3	10.75	10.4	11.1	20.4	19.4	14.85	13.9
Rb	ppm	99.5	114.5	84.7	133	70.2	76.7	143.5	184
Sm	ppm	7.57	8	7.54	8.17	11.25	10.85	9.61	8
Sn	ppm	2	2	2	2	1	1	3	3
Sr	ppm	714	645	746	839	1570	1470	479	699
Ta	ppm	0.7	0.8	0.7	0.7	2.5	2.9	1.1	1.7
Tb	ppm	0.84	0.95	0.87	0.95	1.2	1.25	1.02	0.83
Th	ppm	13.05	13.65	13.1	16.75	7.92	7.62	26.3	37.9
Tl	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Tm	ppm	0.35	0.38	0.38	0.39	0.42	0.44	0.43	0.34
U	ppm	4.1	4.97	4.38	5.6	1.94	1.82	6.86	11.25
V	ppm	231	192	217	204	235	239	46	53
W	ppm	4	4	3	5	3	3	4	6
Y	ppm	24.5	26.5	24.3	25.4	29.6	29.6	26.6	21.1
Yb	ppm	2.32	2.5	2.34	2.59	2.74	2.78	2.76	2.18
Zn	ppm	91	86	94	96	107	105	76	56
Zr	ppm	204	212	203	226	224	237	308	378

LITHOLOGIC COLUMN FOR EAST HALF LOA 30' X 60' QUADRANGLE

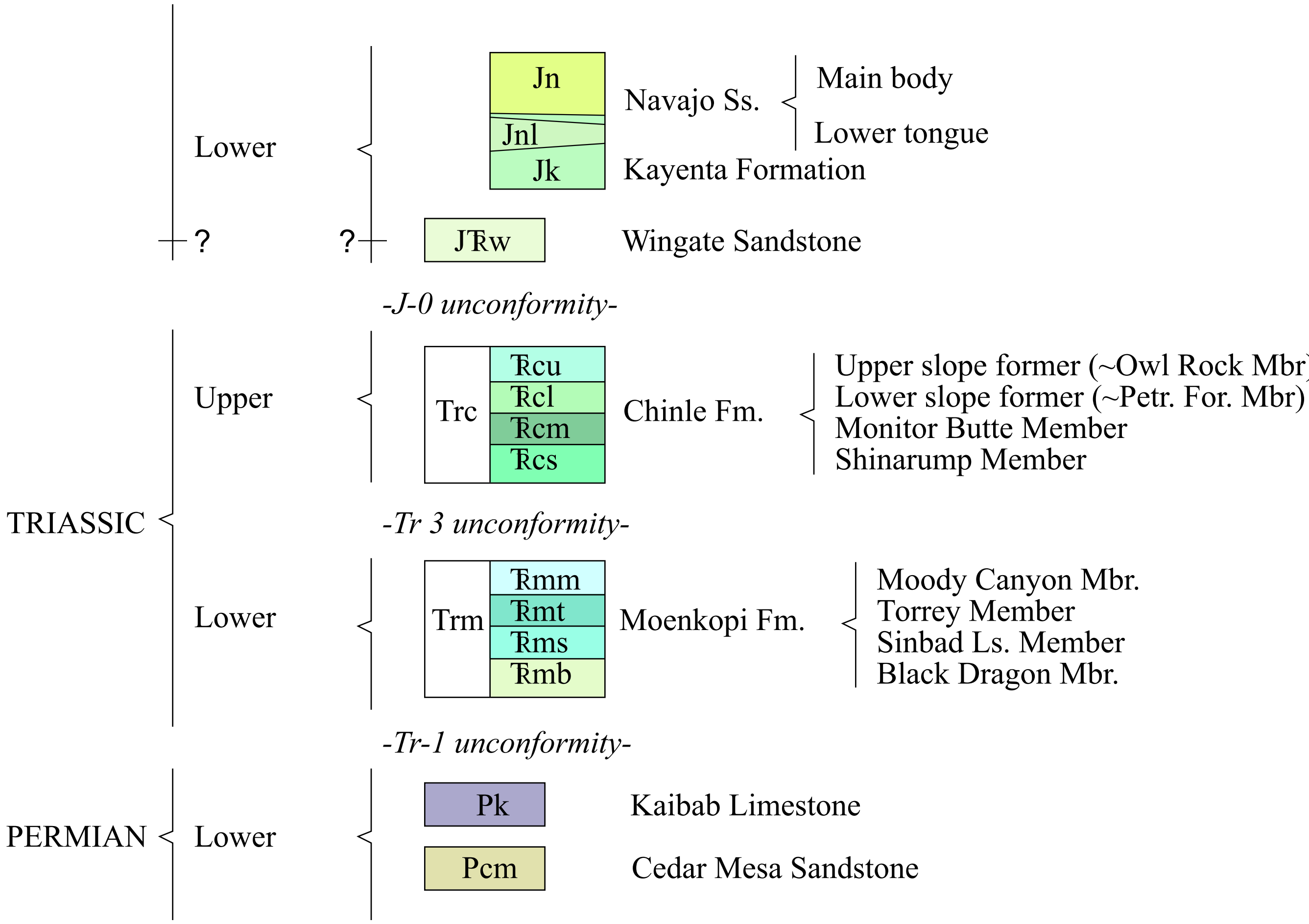
Age		Formation / Member / Unit			Symbol	Thickness Feet (Meters)	
TERTIARY	Mio?-Oligo?	Volcanic rocks			Tbb/Tbf Tlb/Tlf Tvh		400+ (120+)
TERTIARY	Eocene?	Clastic rocks of Flat Top			Tc		400+ (120+)
TERTIARY	Pal?	Carbonate and clastic rocks of Flat Top			Tcc		250+ (76+)
CRETACEOUS	Upper	Tarantula Mesa Sandstone			Ktm		300+ (90+)
CRETACEOUS	Upper	Mancos Shale	Masuk Member		Kmm	2700-3370 (822-1033)	435 (135)
CRETACEOUS	Upper	Mancos Shale	Muley Cyn Sandstone Member	Upper unit	Kmcu	2700-3370 (822-1033)	65-180 (20-55)
CRETACEOUS	Upper	Mancos Shale	Muley Cyn Sandstone Member	Lower unit	Kmcl	2700-3370 (822-1033)	240-270 (70-85)
CRETACEOUS	Upper	Mancos Shale	Blue Gate Member		Kmb	2700-3370 (822-1033)	1200-1400 (365-425)
CRETACEOUS	Upper	Mancos Shale	Ferron Sandstone Member	Upper unit	Kmfu	2700-3370 (822-1033)	125-180 (38-55)
CRETACEOUS	Upper	Mancos Shale	Ferron Sandstone Member	Lower unit	Kmfl	2700-3370 (822-1033)	110-255 (34-78)
CRETACEOUS	Upper	Mancos Shale	Tununk Member		Kmt	2700-3370 (822-1033)	525-650 (160-200)
CRETACEOUS	Upper	Dakota Sandstone			Kd		20-170 (6-52)
CRETACEOUS	L.	Cedar Mountain Formation			Kcm		80-120 (24-37)
JURASSIC	Upper	Morrison Formation	Brushy Basin Member		Jmb	150-590 (44-177)	70-200 (20-60)
JURASSIC	Upper	Morrison Formation	Salt Wash Member		Jms	150-590 (44-177)	50-280 (15-85)
JURASSIC	Upper	Morrison Formation	Tidwell Member		Jmt	150-590 (44-177)	30-110 (9-34)
JURASSIC	Middle	Summerville Formation			Js		140-260 (40-80)
JURASSIC	Middle	Curtis Formation			Jct		10-220 (3-67)
JURASSIC	Middle	Entrada Sandstone			Je		650-800 (200-245)
JURASSIC	Middle	Carmel Formation	Winsor Member	Banded unit	Jcwb	350-1100 (106-334)	120-450 (37-137)
JURASSIC	Middle	Carmel Formation	Winsor Member	Gypsiferous unit	Jcwg	350-1100 (106-334)	80-230 (24-70)
JURASSIC	Middle	Carmel Formation	Paria River Member		Jcpr	350-1100 (106-334)	100-220 (30-67)
JURASSIC	Middle	Carmel Formation	Page Sandstone Member		Jcpc	350-1100 (106-334)	50-200 (15-60)
JURASSIC	Lower	Navajo Sandstone	Main body		Jn	910-1250 (278-381)	800-1100 (244-335)
JURASSIC	Lower	Navajo Sandstone	Lower tongue		Jnl	910-1250 (278-381)	110-150 (34-46)
JURASSIC	Lower	Kayenta Formation			Jk		150-220 (46-67)
JURASSIC	Lower	Wingate Sandstone			JŦw		300-400 (90-120)
TRIASSIC	Upper	Chinle Fm.	Upper slope former (~Owl Rock Member)		Ŧcu	340-745 (130-185)	140-220 (43-67)
TRIASSIC	Upper	Chinle Fm.	Lower slope former (~Petr. For.)		Ŧcl	340-745 (130-185)	90-190 (27-58)
TRIASSIC	Upper	Chinle Fm.	Monitor Butte Member		Ŧcm	340-745 (130-185)	110-190 (34-58)
TRIASSIC	Upper	Chinle Fm.	Shinarump Member		Ŧcs	340-745 (130-185)	0-145 (0-44)
TRIASSIC	Upper	Moenkopi Fm.	Moody Canyon Member		Ŧmm	625-990 (190-300)	260-425 (79-130)
TRIASSIC	Upper	Moenkopi Fm.	Torrey Member		Ŧmt	625-990 (190-300)	250-320 (76-98)
TRIASSIC	L.	Moenkopi Fm.	Sinbad Limestone Member		Ŧms	625-990 (190-300)	60-120 (18-37)
TRIASSIC	L.	Moenkopi Fm.	Black Dragon Member		Ŧmb	625-990 (190-300)	55-125 (17-38)
PERMIAN	Lower	Kaibab Limestone			Pk		300-400 (90-120)
PERMIAN	Lower	Cedar Mesa Sandstone			Pcm		630+ 192+

Lithology



CORRELATION OF BEDROCK FORMATIONS IN EAST HALF OF LOA 30' X 60' QUADRANGLE

Period	Epoch	Unit	Description
	Pliocene	Td, Ts	Dikes and sills
	Miocene?	Tbb/Tbf	Basalt flows of Boulder Mtn. and Flat Top
	Miocene?-Oligocene?	Tlb/Tlf	Latite lava flows of Boulder Mtn. and Flat Top
TERTIARY	Oligocene?	Tvh	Trachyte lava flows and lahars of Hens Hole Peak
		-unconformity?-	
TERTIARY	Eocene?	Tc	Clastic rocks of Flat Top
		-unconformity? (not in contact)-	
TERTIARY	Eocene?-Paleocene?	Tcc	Carbonate and clastic rocks of Flat Top
		-contact not exposed on quadrangle-	
CRETACEOUS	Upper	Ktm	Tarantula Mesa Sandstone
CRETACEOUS	Upper	Km: Kmm	Mancos Shale: Masuk Member
CRETACEOUS	Upper	Km: Kmc (Kmcu, Kmcl)	Mancos Shale: Muley Canyon Ss. Mbr. (upper unit, lower unit)
CRETACEOUS	Upper	Km: Kmb	Mancos Shale: Blue Gate Member
		-unconformity-	
CRETACEOUS	Upper	Km: Kmf (Kmfu, Kmfl)	Mancos Shale: Ferron Ss. Member (upper unit, lower unit)
CRETACEOUS	Upper	Km: Kmt	Mancos Shale: Tununk Member
CRETACEOUS	Upper	Kd	Dakota Sandstone
		-unconformity-	
CRETACEOUS	Lower	Kcm	Cedar Mountain Formation
		-K-0 unconformity-	
JURASSIC	Upper	Jm: Jmb	Morrison Fm.: Brushy Basin Member
JURASSIC	Upper	Jm: Jms	Morrison Fm.: Salt Wash Member
JURASSIC	Upper	Jm: Jmt	Morrison Fm.: Tidwell Member
		-J-5 unconformity-	
JURASSIC	Middle	Js	Summerville Formation
JURASSIC	Middle	Jct	Curtis Formation
		-J-3 unconformity-	
JURASSIC	Middle	Je	Entrada Sandstone
JURASSIC	Middle	Jc: Jcw (Jcwb, Jcwg)	Carmel Fm: Winsor Member (Banded unit, Gypsiferous unit)
JURASSIC	Middle	Jc: Jcpr	Carmel Fm: Paria River Member
JURASSIC	Middle	Jc: Jcpc	Carmel Fm: Page Ss. Member
		-J-2-unconformity-	


Lower
Jn
Navajo Ss.
Main body
Jnl
Lower tongue
Jk
Kayenta Formation
?
?
JTRw
Wingate Sandstone
-J-0 unconformity-
Upper
Trc
TRcu
TRcl
TRcm
TRcs
Chinle Fm.
Upper slope former (~Owl Rock Mbr)
Lower slope former (~Petr. For. Mbr)
Monitor Butte Member
Shinarump Member
TRIASSIC
-Tr 3 unconformity-
Lower
Trm
TRmm
TRmt
TRms
TRmb
Moenkopi Fm.
Moody Canyon Mbr.
Torrey Member
Sinbad Ls. Member
Black Dragon Mbr.
-Tr-1 unconformity-
PERMIAN
Lower
Pk
Kaibab Limestone
Pcm
Cedar Mesa Sandstone

CORRELATION OF QUATERNARY UNITS IN EAST HALF OF LOA 30' x 60' QUADRANGLE